

# NICMOS Camera 2 Coronagraphic Acquisition

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## ABSTRACT

*This report describes the NICMOS Camera 2 coronagraphic acquisition mode procedures for point sources, onboard software for faint targets and “Reuse-Offset” for bright sources. A bright source is any target that will saturate the NIC2 detector using the shortest ACQ exposure time (0.228 seconds) with the narrowest filter (F187N). Onboard flight software should not be used to acquire a bright target.*

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## 1. Introduction

The Near Infrared Camera and Multi-Object Spectrograph (NICMOS) is a second generation Hubble Space Telescope (HST) instrument. An in-depth description of NICMOS can be found in the NICMOS Instrument Handbook.

Light enters NICMOS through an aperture located near the optical axis of the HST OTA and is redirected by several mirrors to the Field Divider Assembly (FDA) mirror. The incoming light beam is split by the FDA into three paths, one for each camera, and the beams are refocused onto the detectors. A 0.3 arcsec radius hole was bored through the NIC2 FDA mirror face. The hole, combined with a cold mask, provides coronagraphic imaging capability in Camera 2 (NIC2). The useful radius of the coronagraphic hole is  $\sim 0.4$  arcsec. In the standard onboard acquisition procedure, a target is imaged in a region of NIC2 near the hole, centroiding (to determine the target’s position) is performed, offsets automatically calculated, and the telescope commanded to slew to position the target into the hole. This procedure is generally specified by a single Phase II exposure line, using ACQ mode.

## 2. Movement of the Coronagraphic Hole

The NICMOS dewar anomaly has caused the coronagraphic hole to migrate to different locations on the detector. The position of the hole on the detector moves  $\sim 0.25$  pixel in

three orbits. This movement causes a problem for the onboard Target Acquisition (TA). Currently, the Flight Software (FSW) will find the target and slew the telescope to position the target into the hole. The target must be positioned in the hole to a fraction of a pixel to reduce PSF diffraction and scattered light. Therefore, the precise location of the coronagraphic hole is needed to achieve coronagraphic imaging.

### **3. Coronagraphic Flight Software**

A FSW fix has been approved and will be implemented in mid-November 1997. The new flight software will determine the location of the coronagraphic hole, locate the star, determine the offset, and slew the telescope to position the target in the hole.

The location of the coronagraphic hole is determined from pointed flat field observations. The pointed flat field images are short ACCUM exposure (7.514 seconds) F160W filter observations with calibration Lamp 1 on (flat field) and off (background). The flight software combines the two background and two flat field images and subtracts the coadded background from the coadded flat field images. A small 32 x 32 pixel subarray containing the hole is extracted and a small checkbox is used to find the location with the minimum total counts. This is done automatically, as part of the acquisition procedure.

The acquisition image of the target is specified on the exposure line and any filter or ACQ exposure time can be used to image the target. The target is positioned within a square area 128 x 128 pixels aperture (center at 156,128). Two ACCUM images of equal exposure are obtained. The flight software subtracts a constant bias value from each image and coadds the images to produce a single image in which cosmic rays have been removed. The brightest point source in the acquisition aperture is determined by summing the counts in a checkbox of size 3x3 detector pixels. The algorithm passes the checkbox over the entire acquisition aperture. The brightest checkbox is selected and the fractional pixel location of the target determined.

The quantized legal NICMOS ACQ exposure times are computed just as the exposure times for the ACCUM mode, except the minimum time is different:

$$T_{acq} = TPG\_TIME + 0.228 \text{ sec}$$

The legal TPG\_TIME exposure times are given in the HST Phase II Proposal Instructions, Table 11.4, page 11-25.

The measured position of the coronagraphic hole and the target in detector pixels are saved in the engineering and is not readily available. The position of the hole is being monitored.

The combined images (background, flat field, and acquisition image) are not saved, but the two background, two flat field, and two acquisition images are sent to the ground. These images are written to the distribution tape sent to the PI.

## 4. Onboard Coronagraphic Acquisition

The acquisition procedure described in Section 3 is invoked by a single RPS2 exposure line. This exposure line should have Config=NIC2, Opmode=ACQ, Aperture=NIC2-ACQ, and an appropriate ACQ exposure time and selected filter. See sample exposure line below.

Residual errors of  $\sim 1/6$  pixel maybe introduced into the calculated position of the hole. This is not a problem for most coronagraphic observations, but might be a problem for repeat NICMOS ACQ exposures during the same orbit or visit. If the spacecraft is rolled and a second acquisition performed of the same target, the two coronagraphic images of the target in the hole will probably not be perfectly aligned.

The observer needs only to specify a NICMOS onboard Acquisition (ACQ) to acquire the target. The software schedules the background and flat field observations first, followed by the observations of the target. The default exposure for the pointed background and flat field observations is 7.514 seconds. If the target will saturate the NIC2 detector in 7.514 seconds with the F160W filter, a residual image will be created that will contaminate the on target ACQ observation. This persistence image may introduce some error into the centroiding algorithm. The observations following the ACQ should specify the Aperture=NIC2-CORON.

Sample Phase II exposure lines:

```
Exposure_Number: 1
  Target_Name: targetname
    Config: NIC2
    Opmode: ACQ
    Aperture: NIC2-ACQ
    Sp_Element: F187N
    Wavelength: 1.87
Optional_Parameters:
Number_of_Iterations: 1
  Time_Per_exposure: 13.409 S
Special_Requirements: ONBOARD ACQ FOR 2
  Comments: onboard acquisition of target. The filter
            and exposure are selected by the observer
            for a specific target.

Exposure_Number: 2
  Target_Name: targetname
    Config: NIC2
    Opmode: ACCUM
    Aperture: NIC2-CORON
    Sp_Element: F160W
    Wavelength: 1.60
Optional_Parameters: NREAD=1
Number_of_Iterations: 1
  Time_Per_exposure: 7.514 S
Special_Requirements:
  Comments: This is the observer specified coronagraphic
            observations. ACCUM or MULTIACCUM can be used
            with other filters and exposure times.
```

## 5. Bright Target Acquisition

Bright targets will saturate the NIC2 detector resulting in possible failure of the onboard software to successfully acquire and position the target into the coronagraphic hole. For NIC2 coronagraphic acquisition, any target that will saturate the detector in a 0.228 second exposure should be considered a bright target.

STScI does support “reuse-target-offsets” and the OSS and PODPS Unified System (OPUS) does have software to centroid bright targets by using the outer portion of the PSF. Images of the target and coronagraphic hole are obtained a few orbits in advance of the coronagraphic observations, and sent to the ground. OPUS staff will assist the PI in identifying the target, centroiding, and determining offsets. OPUS staff will then provide the offsets to MOSES personnel for uplink to the spacecraft in advance of the coronagraphic observations. The ultimate responsibility for determining the offsets will be the PI, who must be present at STScI at the time of the target/hole location observations.

The observer needs to specify two background, two flat field, and two on-target exposures. The recommended pairs of images are needed to remove cosmic ray hits. Exposures using LAMP values other than NONE are restricted to engineering and calibration programs. An exception to this rule is when the LAMP observations are necessary for bright target acquisitions. The observer needs to add the proposal AVAIL\_OK mode qualifier to the top of the Phase II template. Here is an example.

```
Proposal_Category: GO
                Cycle: 7
                AVAIL_OK: YES
```

It is recommended that target be moved out of the aperture during the background and flat field observations. We recommend an offset of 25 arcseconds. POS TARGs can be used to move the target out of the aperture.

The shortest exposure time possible should be specified for the on-target observations. This will avoid contamination from residual charge (persistence image).

The STScI scheduling software will create links between the first and second visits assuring that the target/hole visit and the associated coronagraphic science visit are scheduled at the same orientation. This is a requirement for usage of the SAVE/USE OFFSET capability. The SAME ORIENTATION special requirement is implicit and need not be specified directly.

Sample Phase II exposure lines:

```
                Visit_Number: 1
Visit_Requirements:
On_Hold_Comments:
                Visit_Comments: This is the target/hole location visit.

                Exposure_Number: 1
                Target_Name: targetname
                Config: NIC2
```

```

        Opmode: ACCUM
        Aperture: NIC2-CORON
        Sp_Element: F160W
        Wavelength: 1.60
    Optional_Parameters: NREAD=1
    Number_of_Iterations: 2
        Time_Per_Exposure: 7.514 S
    Special_Requirements: RT ANALYSIS
        POS TARG 0.0,25.0
    Comments: This is the background observation for the
              following flat field exposures. These
              observations are used to determine the
              position of the coronagraphic hole. They
              need to be sent to the ground.

    Exposure_Number: 2
        Target_Name: targetname
        Config: NIC2
        Opmode: ACCUM
        Aperture: NIC2-CORON
        Sp_Element: F160W
        Wavelength: 1.60
    Optional_Parameters: NREAD=1,LAMP=FLAT1
    Number_of_Iterations: 2
        Time_Per_Exposure: 7.514 S
    Special_Requirements: RT ANALYSIS
        SAME POS AS 1
    Comments: These are the flat field exposures for the
              following real-time acquisition. The
              observations are used to determine the position
              of the coronagraphic hole. They need to be sent
              to the ground. RPS2 will generate an error
              message about LAMP usage. LAMP usage normally
              only for engineering proposals. Disregard error
              message.

    Exposure_Number: 3
        Target_Name: targetname
        Config: NIC2
        Opmode: BRIGHTOBJ
        Aperture: NIC2-CORON
        Sp_Element: F187N
        Wavelength: 1.87
    Optional_Parameters: NREAD=1
    Number_of_Iterations: 2
        Time_Per_Exposure: 0.0512 S
    Special_Requirements: POS TARG 6.374,-6.472
        RT ANALYSIS
    Comments: These are the target acquisition images. A
              0.0512 sec mode=BRIGHTOBJ exposure will take
              14.5 minutes to complete. They need to be sent
              to the ground

    Exposure_Number: 4
        Target_Name: targetname
        Config: NIC2
        Opmode: ACCUM
        Aperture: NIC2-CORON
        Sp_Element: F187N
        Wavelength: 1.87
    Optional_Parameters: NREAD=1
    Number_of_Iterations: 2
        Time_Per_Exposure: 0.598 S
    Special_Requirements: POS TARG 6.374,-6.472

```

```

RT ANALYSIS
SAVE OFFSET OFF01
Comments: These are the images of the target which will
          be used to determine the location of the
          target. They need to be sent to the ground.

Visit_Number: 2
Visit_Requirements: AFTER 1 BY 3 ORBITS TO 5 ORBITS
On_Hold_Comments:
Visit_Comments: This is the associated coronagraphic science
                visit. The special requirement "USE OFFSET
                OFF01" needs to be on every line that uses it,
                otherwise the pointing will revert to the
                previous setting.

Exposure_Number: 1
Target_Name: targetname
Config: NIC2
Opmode: ACCUM
Aperture: NIC2-CORON
Sp_Element: F160W
Wavelength: 1.60
Optional_Parameters: NREAD=1
Number_of_Iterations: 2
Time_Per_Exposure: 7.514 S
Special_Requirements: POS TARG 6.374,-6.472
                    USE OFFSET OFF01
Comments: This is the first observer specified
          coronagraphic observation. ACCUM or MULTIACCUM
          can be used with other filters and exposure
          times. This observation uses the target offsets
          determined on the ground using data from
          visit 1.

Exposure_Number: 2
Target_Name: targetname
Config: NIC2
Opmode: ACCUM
Aperture: NIC2-CORON
Sp_Element: F160W
Wavelength: 1.60
Optional_Parameters: NREAD=1
Number_of_Iterations: 2
Time_Per_Exposure: 7.514 S
Special_Requirements: SAME POS AS 1
                    USE OFFSET OFF01
Comments: This is the second observer specified
          coronagraphic observations. ACCUM or MULTIACCUM
          can be used with other filters and exposure
          times. This observation uses the target offsets
          determined on the ground using data from
          visit 1.

```

Using the "SAME POS AS" special requirement implicitly replicates the "POS TARG" into the following exposure lines.

## 6. Minimum Exposure Times

NICMOS exposure times are quantized to specific values depending on the timing pattern for the operation mode. The minimum ACCUM exposure time for NREAD=1 is

0.598 seconds, while the minimum MULTIACCUM exposure time is 0.203 seconds for exposure sequence SCAMRR with NSAMP=1. If the target will saturate the detector pixels in less time than the minimum MULTIACCUM exposure of 0.203 seconds, then mode BRIGHTOBJ should be considered for the acquisition image. The shortest BRIGHTOBJ exposure time is 0.001024 seconds. However, the user should be warned that there is considerable overhead for this imaging mode. A 0.0512 second mode=BRIGHTOBJ exposure will take approximately 14.5 minutes to complete the exposure. This results from reading out the entire array, four pixels at a time.

Persistence will again be a major problem as each pixel is only reset once before the exposure readout in mode=BRIGHTOBJ. While the detector is being read out four pixels at a time, the pixels containing the bright target will become seriously saturated, and the single reset of each pixel will not remove all the residual charge.

See HST Phase II Instructions section 11.5, page 11-22 for details about mode=BRIGHTOBJ. Questions concerning mode=BRIGHTOBJ should be directed to the Contact Scientist assigned to the coronagraphic program, or to the STScI Help Desk (help@stsci.edu).

## **7. NICMOS Focus Selection**

There is a slight difference in the NIC2 focus between the optimal center of the detector and the position of the coronagraphic hole. Coronagraphic observations will be degraded slightly when the nominal NIC2 focus position is used. The degradation is wavelength dependent and will become progressively worse for longer wavelengths. Specifying the aperture=NIC2-CORON will move the PAM to produce a focused star image at the position of the coronagraphic hole.

## **8. Disclaimer**

The target coordinates should be in the HST Guide Star Catalogue Reference Frame, and target positions derived from the Phase II DSS (digitized sky survey) from the web are in this reference frame. Relative coordinates in the HST field of view should be good to 0.5" (Taff et al, 1990, ApJ, 353, L45.). It is unlikely that blind pointing of a target into the NICMOS ACQ acquisition aperture will result in centering the target in the square 128 x 128 pixel (9.6"x9.6") aperture. However, the target will most likely be found somewhere within the acquisition aperture.

Targets with high proper motions or parallax should have recent Epoch proper motions and parallax values listed in the Phase II template. For onboard NICMOS coronagraphic acquisition, the observer should verify that no object in the NICMOS NIC2 ACQ field of view will be brighter than the target.

## **9. SMOV Coronagraphic Results**

The results from SMOV coronagraphic verification programs 7052 and 7157 can be found on the NICMOS IDT web page (<http://nicmosis.as.arizona.edu>) under Glenn Schneider's directory (gschneid).